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(54) Title: **SENSOR**

(57) Abstract [Already in English]

Description

Sensor

A capacitive sensor for both absolute and relative pressure measurements is known from the DE 33 10 643. This sensor has a first and second electrode, which are at a distance from one another and which form a measurement capacitance. The first electrode is disposed on a first substrate body and the second electrode on a second substrate body. These substrate bodies are laterally connected to one another, and the second substrate body in the region of the second electrode is constructed as a diaphragm which can be deformed by pressure. The capacitive output signals of the sensor are conducted to an external evaluation unit and are evaluated there.

It is the object of the invention to create a sensor whose structure offers the broadest possible fields of application.

This object is achieved by a sensor with the characteristics given in Claim 1. Advantageous further developments of the sensor are presented in the subclaims.

The inventive sensor has a signal source to emit a physical signal and a signal detector which is independent of the signal source and which is situated at a distance therefrom. The signal detector receives the physical signal where the detector is located, after the physical signal has traversed the space between the signal source and the signal detector and has thereby been changed. The signal received in the signal detector is conducted to an evaluation unit, which evaluates the received signal with the help of stored information about the signal source and thus about the emitted physical signal. The evaluation preferably

includes a comparison of the expected signal, in terms of information about the signal source

and thus about the emitted signal, with the actually received signal. Information is thus gained about the relative distance, that is a variable which is determined on the one hand by the spatial distance between the signal source and the signal detector and on the other hand also by the transmission properties of the region between the signal source and the signal detector. This relative distance thus must be distinguished from the purely geometrical distance of the signal source from the signal detector.

Through this type of interaction, if the geometric distance is known, information can be obtained about a change of the transmission behavior. From this, certain physical properties, such as density changes, temperature changes, or changes of the transport speed, or a change of the throughflow quantity or also their absolute values can be determined. On the other hand, if the transmission conditions are constant, information can be obtained about the change of the geometrical distance between the signal source and the signal detector. If the distance change is caused by an external force, a pressure, or an acceleration or the like, the change of these variables or their absolute values can be determined from this. Because the signal source and the signal detector are mutually independent and separate units, which ideally are not even connected electrically or electronically, it is possible to avoid mutual influences, such as are known in connection with the capacitive sensor of the DE 33 10 643, where these mutual influences result from the two electrodes which form a measurement capacitance.

Among the large number of physical signals, radioactive signals, electromagnetic signals, optical signals, pressure variations, or thermal signals have proven to be especially suitable physical signals. By constructing the signal source and the signal detector on a common substrate or on two separate, closely spaced

substrates, the sensor dimensions can be greatly reduced. This greatly extends the possible field of application of such a sensor, for example in the pharmaceutical industry or the chemical industry, where one deals with very high-grade or expensive substances with small volumes.

It has proven especially advantageous to keep the distance between the signal source and the signal detector constant, especially by a self-enclosed, mechanically rigid structure of one or more substrates, and thereby make it possible to detect and evaluate changes in the transmission properties in the spatial region between the signal source and the signal detector. Such a sensor is especially suited to measure changes in the gas density or in the transport speed or in the throughflow quantity or in the temperature distribution, or the absolute values thereof.

It also proves to be especially advantageous to keep the transmission properties constant in the region between the signal source and the signal detector, and thereby make it possible to measure the distance between the signal source and the signal detector or its change. The transmission properties are here kept constant especially in that the space between the signal source and the signal detector has a uniform and permanent structure. Care must especially be taken to keep the temperature constant, to keep the composition constant, and to make the space isotropic, as well as similar variables. It has proven especially advantageous to fill the space completely with a noble gas or still better with a vacuum. In this case, by comparing the received signal with the information about the emitted signal, information can be obtained about the distance and its change.

A preferred embodiment of the invention comprises a control unit which is connected to the signal source and controls it. Furthermore, the control unit is connected to the evaluation unit, thus updating the information about the signal source for the purpose of evaluating the received physical signals. Furthermore, it is possible, by means of this control unit, to operate the evaluation unit and, as a supplement to this, also the signal detector only for the time during which reception and evaluation of an emitted physical signal by the signal source is expected. This design makes it possible to reduce significantly the electrical consumption of the sensor over an extended period of time, which again opens up a greater field of application, especially in remote measurement stations and especially without a connection to an electrical network.

The evaluation unit and/or the control unit preferably is disposed in the substrate body or bodies, especially in the region of the signal source or of the signal detector, thus achieving a higher integration density of the sensor. This very advantageously affects the size of the sensor. Furthermore, such an arrangement proves electronically very advantageous, since very short signal paths can be realized thereby and thus only minimal signal losses can occur, leading to an especially advantageous signal-to-noise ratio for the received physical signal. Furthermore, such an arrangement proves insensitive to external electronic noise influences, for example through the constantly present electromagnetic smog, which is especially important for application in the automotive field. Such a sensor, with an electronic evaluation unit and/or control unit integrated into the substrate body thus proves especially suitable for use in the automotive field. The control unit preferably is implemented in the substrate body separately from the evaluation unit. The control unit preferably is arranged in the region of the signal source,

especially below this, while the evaluation unit is arranged in the substrate body in the region of the signal detector and especially below this. If the signal source and the signal detector are constructed separately on separate substrate bodies, this separation will also be realized for the control unit and the evaluation unit. This most thoroughly excludes mutual interference of the electronic units.

It has proven especially advantageous for the evaluation unit to have one or more signal-amplifying elements in the substrate body. By the arrangement in the substrate, especially below the signal detector, they can make an optimal contribution, since it is precisely the short signal paths that yield a very good signal-to-noise ratio and thus a good resolution. This arrangement proves to be an especially suited design of the inventive sensor.

According to another embodiment of a sensor, in which the distance between the signal source and the signal detector is variable, the substrate body is designed as a diaphragm in the region of the signal receiver and/or the substrate body in the region of the signal detector. It changes its position due to an external force or due to an external pressure or due to an acceleration of the sensor, and thereby changes the distance between the signal source and the signal detector. This allows a measurement of the externally acting force or the pressure or the acting acceleration or their changes. Thus, in a manner that is simple in its production engineering and that is sparing in its use of space, a universally suited sensor can be created for the measurement of forces, pressures, or accelerations, or the like.

Preferably, a sensor with a diaphragm has an additional damping device to damp undesirable vibrations, thus yielding measurement results

of substantially better quality, since interference with the measurement values by undesirable vibrations, especially due to resonances in the sensor, and especially in the region of the diaphragm, can be excluded by such a damping device. For example, such damping devices can be formed by reinforcements in the region of the diaphragm, whereby the resonance frequencies of the diaphragm can be moved into specific, less troublesome regions, or its tendency to vibrate can be markedly reduced. Furthermore, it has proven advantageous to fill up the closed volume of the sensor in the region of the diaphragm with a gas of higher density, and thereby achieve better damping. It has also turned out appropriate to damp the region of the diaphragm by a magnetic force, by disposing one or more magnets at suitable points around the diaphragm and equipping the diaphragm itself with an appropriate magnet. The magnetic interaction of these magnets causes the diaphragm to take up its equilibrium position faster and thus acts as a damping mechanism.

According to a preferred embodiment of the invention, the signal source and/or the signal detector are constructed in such a way that they are suited for space-resolving measurements. This can be done by the signal detector having spatially separated segments, which are activated by the physical signal in a spatially differentiated way, and which are evaluated in a spatially differentiated way by an appropriate electronic apparatus for the space-resolving processing of the received physical signals. This apparatus for space-resolving processing preferably is disposed within the substrate body, and especially below the signal detector in the region of the evaluation unit. This leads to advantages comparable to those of the arrangement of the evaluation unit in the substrate body. This space-resolving measurement and evaluation makes it possible to obtain specific information about the type of excursion of the diaphragm, its mechanical condition, especially its

fatigue state, and thus the possibility of healing the diaphragm and the sensor arrangement. This sensor therefore proves to be one which detects failure due to material fatigue of the diaphragm at an early stage and provides the user with the information that replacement of the inventive sensor is necessary.

A sensor in which the physical signal consists of electromagnetic radiation has proven especially advantageous. Here, the signal source and/or the signal detector is realized by an antenna consisting of conductor tracks on or in the substrate body. It is thus possible to create a complete sensor by an all-through production process of the substrate body, with the electrical conductor tracks implemented thereon or therein, and with electronic apparatuses, without additional, separate, other production processes, and without the additional attachment of separately produced signal sources or signal detectors. This sensor therefore proves very simple to produce as regards its production engineering, also very economical, as well as very little prone to trouble. This makes this sensor very suitable for mass production, for example in the automotive field or also for use under extreme conditions, where there is an extaordinary need for quality.

The control unit of the sensor preferably is connected to the signal source and to the evaluation unit such that the current properties of the signal source are taken into account in the evaluation and thus in the comparison of the emitted physical signal and the expected physical signal with the actually received physical signals. If a change of the properties of the signal source results in a change of the emitted physical signal, for example by a diminished activity of a radioactive radiation source, this information is made available by means of the connecting line of the electronic

arrangement to the evaluation device, also called evaluation unit, and is taken into account in the evaluation. It is thus possible to take changes of the signal source into account automatically during the evaluation. This makes the measurement result of the sensor much more reliable.

The invention is explained below in terms of the drawings.

Figure 1 shows a first inventive embodiment of the sensor with a radioactive signal source and a space-resolving signal detector to measure the throughflow quantity.

Figure 2 shows a second inventive embodiment of the sensor as a pressure sensor.

Figure 3 shows an exemplary circuit structure of an inventive embodiment of a sensor.

Figure 1 shows an inventive sensor for throughflow measurements. The sensor has a first substrate body 1, associated with a second substrate body 2 situated at a distance. The signal source 3 is situated on the first substrate body 1 and faces the second substrate body 2. The signal detector 4 is situated on the second substrate body 2 and faces the first substrate body 1. It is divided into four individual, spatially separated detector elements 4a, 4b, 4c, 4d. An electronic evaluation unit 5 is situated in the interior of the second substrate body 2. It is connected to the individual signal detector elements 4a-4d, and it amplifies and evaluates the received physical signals. This evaluation also comprises a differentiation with respect to the location of the individual signal detector elements, and thus an evaluation with respect to the spatial development of the physical signal. This leads to a representation of the throughflow quantity through the spatial region 6 between the

signal source 3 and the signal detector 4.

The signal source 3 shown in this embodiment is a thermal source. If the intermediate space 6 between the signal source 3 and the signal detector 4 is traversed by a slowly flowing fluid, the thermal energy is deflected only slightly in the flow direction; at a higher flow rate, it is deflected more strongly. Depending on the measure of deflection, various signal detector elements are excited, from which a conclusion can be drawn concerning the flow rate of the substance traversing the space 6, and from this a measurement of the throughflow quantity can also be gained.

In this embodiment, the signal source 3 operates completely independently of the signal detector 4 and of the evaluation unit 5. Consequently, it is also not necessary to connect the signal detector 3 electrically to the signal detector 4 or to the evaluation unit 5. This is especially advantageous since it essentially excludes all problems associated with sealing electrical connections against the flowing measurement substance and thus excludes the risk of malfunction or total failure of the sensor.

The construction of the sensor with the two substrate bodies 1, 2 and the signal source 3 and signal detector 4, together with the integrated evaluation unit 5, situated thereon create an extremely small sensor structure. It can thus also be used in situations where, for example, only small amounts of substance are present, whose throughflow rate or throughflow quantity is to be measured. Such a throughflow quantity sensor proves to be especially suitable for the pharmaceutical industry or for test laboratories, prototype laboratories and analytical laboratories of the chemical industry.

Figure 2 shows an inventive pressure sensor comprising a first substrate body 1 and a second substrate body 2, such that a signal detector 4 is situated on the second substrate body 2 and an electronic evaluation unit 5 is integrated into the second substrate body 2, so as to process the physical measurement signals. Integrating the evaluation device 5 into the substrate body 2 directly at the signal detector 4 utilizes the available space for the entire sensor very efficiently. Furthermore, the signal paths from the signal detector 4 to the evaluation unit 5 are considerably shortened, resulting in an especially reliable evaluation of the measurement signals. The first substrate body 1 is formed in such a way that it has a diaphragm which can be deformed by pressure. Usually the pressure is exerted on the membrane in the direction of the arrow. A signal source 3 is situated in the area of the diaphragm, on that side which is associated with the signal detector 4. If the diaphragm is deformed through the action of an external pressure, the signal source 3 is thereby changed in its position, and this causes its distance from the signal detector 4 to change. If the physical signal emitted by the signal source 3 has a dependence on the distance it traverses before being received by the signal detector 4, information about the traversed path and thus about the distance between the signal source 3 and the signal detector 4 can be obtained from the evaluation of the received physical signal by the evaluation unit 5. Information thus can be obtained about the pressure exerted on the diaphragm. This information can relate both to the relative pressure and absolute pressure.

In the chosen embodiment, the substrate bodies 1, 2 are made of silicon. This makes integration of the evaluation unit 5 especially simple. In addition, silicon has especially advantageous mechanical properties for the deformable diaphragm 5. The signal source 3 and the signal detector 4 are formed on their respective substrate bodies 1, 2, by conductor tracks with a specific shape and size

so that on the one hand they act as a transmission antenna and on the other hand as a reception antenna for an appropriate electromagnetic signal. The electromagnetic signal can be specified by the shape and size of the corresponding conductor tracks, so that the influences of interfering external electromagnetic fields can be reduced to a minimum. As described before, the received electromagnetic signal depends on the transmission properties of the space 6 between the signal source 3 and the signal detector 4, the spacing being especially and centrally important. If the space is filled by a homogeneous substance, which is non-specific in its electromagnetic transmission properties except for the transmission path, this design of the sensor proves to be especially suitable, for example, to measure exactly the pressure on the diaphragm. If, in addition to the dependence of the transmission properties on the transmission path, there exists a dependence on temperature, this temperature dependence can be taken into account in the evaluation by the evaluation unit 5 through the use of a well-known thermometer. In such a case, however, this sensor inversely can also be used as a temperature sensor, if the distance between the signal source 3 and the signal detector 4 is held constant or can be determined in another way.

Figure 3 shows an exemplary circuit diagram of an inventive sensor. It shows the transmission source 3, which is separated from the signal detector 4 by the spatial region 6. The signal source 3 transmits a physical signal in the direction of the signal detector 4. This signal is indicated by the arrow B and traverses the spatial region 6.

The sensor has a control unit 7, which is connected to the transmission source 3 by a control line, and actuates said transmission source to emit a certain physical signal at a specific time. Furthermore, the control

unit 7, which preferably is integrated in the substrate body 1 close to the signal source 3, is connected to the signal detector 4. The evaluation unit 4 is integrated into the second substrate body 2, which is associated with the signal detector 4. By means of the connecting lines to the signal detector 4 and to the evaluation unit 5, these are switched on specifically in knowledge of the control data of the signal source and the expected reception time of the physical signal. This guarantees that the signal detector 4 will detect the physical signal emitted by the signal source 3 and that the evaluation unit 5 will make an appropriate evaluation. Outside this time window, necessary for reliable operation, the signal detector 4 or also the evaluation unit 5 is turned off, thus significantly reducing the energy consumption of the sensor over time. The like also holds for the signal source 3.

The evaluation unit 5 is connected to the control unit 7 and the signal detector 4, through which connection the received physical signal is conducted to the evaluation unit 5. However, it is also connected to an external display 9. The measurement variables measured by the evaluation unit 5, such as pressure, force, acceleration, throughflow rate, throughflow quantity, temperature, or the like, are displayed to the user on this display unit.

List of Reference Symbols

1 First substrate body

2 Second substrate body

3 Signal source

4 Signal detector

5 Evaluation unit

6 Spatial region

7 Control unit

8 Display